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The Use of an Intermediate Wavelength Laser for Alignment to Inertial Confinement Fusion Targets

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Abstract

The conceptual design of the National Ignition Facility's 192 beam laser incorporates an intermediate-wavelength low-power alignment beam that is injected in the pinhole plane of the final spatial filter. The proposed system overcomes the principal target alignment difficulties inherent in a laser that converts the optical wavelength of each beam immediately before it enters the target focusing optics and that requires a significant cool down time for the amplifiers between shots.

Two absolute references for focused light in the high power NIF laser system are the pinhole in the final spatial filter of each beam, where the wavelength is 1053 nm, and the target illuminated by all the beams, where the wavelength is 351 nm. The optics between these two locations are designed to accurately relay an image of the first reference point onto the second while accounting for the wavelength change of the desired light and laterally and longitudinally displacing the residual 1053 and 526.5 nm light from the target by dispersion.

A low power alignment beam of any wavelength could be injected in the region of the final pinhole, but in the general case, the injection point would have to be offset both laterally and longitudinally to be reimaged at the correct position on the target. The two dimensional offset would have to be done with great precision, because the requirement for accuracy in laser alignment to the target in the National Ignition Facility is $\leq 50\ \mu m$ rms over all beams including all sources of error. This means that some individual alignment steps, including substituting the low power alignment beam for the full system beam must be accomplished with five to ten times better accuracy.

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Substantial improvement in the accuracy of injection is achieved by choosing the unique alignment wavelength that eliminates the longitudinal offset. This alignment concept is illustrated in the figure on the next page. At a wavelength of approximately 389 nm, the effects of dispersion in the spatial filter lens and final focus lens cancel; thus, the alignment beam focuses at the same distance from the focus lens as the 3ω shot beam. Lateral dispersion due to wedges in the delivery system (principally the off-axis focus lens) is not compensated. However, because the injection point offset is now entirely in the plane of the pinhole, it can be accomplished with greater accuracy.

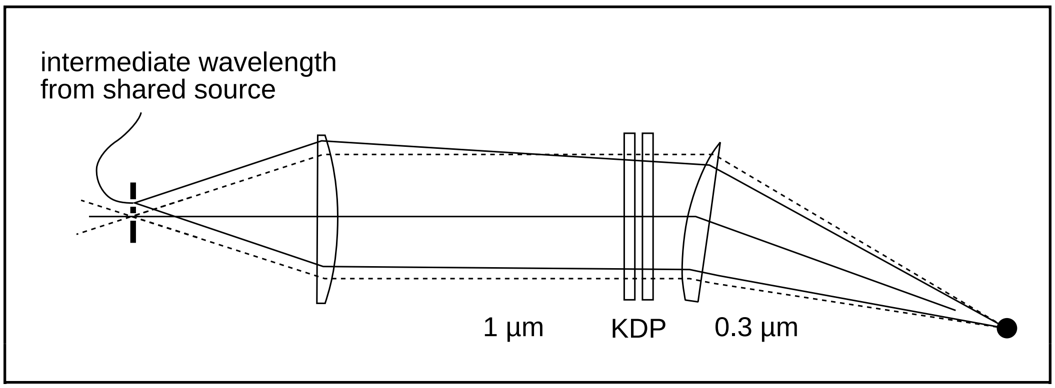

Figure. There is a particular value of wavelength for which the pinhole plane of the last spatial filter is reimaged at the target position with no longitudinal offset.

Alignment of the main part of the laser chains cannot proceed until the amplifiers have cooled sufficiently from the previous shots. Any task that depends on an alignment beam passing through them will be subject to thermal drift during the laser recovery period. Since the final spatial filter follows the amplifiers, an alignment beam injected there can be used immediately after a shot, and the positioning of beams on the target can be pursued independently of other alignment tasks.

We will describe the intermediate wavelength laser alignment concept and the dependence of the alignment beam wavelength on the optical design of the laser beam delivery system. The implementation and feasibility of the approach will be discussed, including issues relating to aberrations of the alignment beam, mirror coating design, index of refraction tolerances, lens fabrication tolerances, intermediate wavelength accuracy, and lateral offset positioning requirements.